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A
New METHOD
For Diſcovering the
LONGITUDE
BOTH AT
SEA and LAND,

Humbly Propoſed to the Conſideration of the PUBLICK.

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BY

William Whiſton, M. A. ſometime Profeſſor of the Mathematicks in the Univerſity of *Cambridg*.

and

Humphry Ditton, Maſter of the New Mathematick School in *Chriſt*'s *Hoſpital*, London.

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TO

The Right Honourable THOMAS *Earl of* Pembroke *and* Montgomery.

The Right Reverend Father in God PHILIP *Lord Biſhop of* Hereford.

The Right Reverend Father in God GEORGE *Lord Biſhop of* Briſtol.

The Right Honourable THOMAS *Lord* TREVOR, *Lord Chief Juſtice of the Common Pleas.*

The Admirals of the Red, White and Blue Squadrons.

The Firſt Commiſſioner of the Admiralty. 60 f

The Firſt Commiſſioner of the Navy.

The Firſt Commiſſioner of Trade. 8

The Maſter of Trinity-Houſe.

The Hon. Sir THOMAS HANMER, *Bart. Speaker of the Honourable Houſe of Commons.*

The Hon. General STANHOPE.

The Hon. FRANCIS ROBERTS, *Eſq;*

Sir Isaac Newton, *Preſident of the Royal Society.*

William Lownds, *Eſq;*

William Clayton, *Eſq;*

Mr. John Flamsteed, *Aſtronomer Royal.*

Dr. Edmund Halley, *Savilian Profeſſor of Geometry.*

Mr. John Keill, *Savilian Profeſſor of Aſtronomy.*

Mr. Sanderson, *Lucaſian Profeſſor of the Mathematicks.*

Mr. Roger Cotes, *Plumian Profeſſor of Aſtronomy.*

Commiſſioners appointed by Act of Parliament for the Diſcovery of the LONGITUDE.

This New Method for that Diſcovery is with all due Submiſſion humbly Dedicated by

The Authors.

THE INTRODUCTION.

BEfore we come to give an Account of this our New Method for the Diſcovery of the Longitude, both by Sea and Land, which we here take leave humbly to propoſe to the Conſideration of the Publick, we think it reaſonable to premiſe ſomewhat by way of Introduction: To give ſome Account of the Nature of the Problem before us; to ſpeak a little of the Methods hitherto try'd, and the Reaſons of their ill Succeſs; and to add a brief Hiſtorical Narration, from what Occaſions and by what Steps this our Method was firſt diſcover'd, and has arriv'd at its preſent Degree of Maturity.

As to the Problem it ſelf, the Invention of the Longitude; it is plainly this: To diſcover in ſome meaſure a like ſure way of frequently knowing, how far we are diſtant, on the Earth Spherical Surface, in Degrees, from any known Meridian, Eaſtward or Weſtward; as we can eaſily know, almoſt at any time, how far we are diſtant, in Degrees, on the ſame Surface, from the middle Circle or Equator, Northward or Southward. Now in this Caſe it muſt be noted, that as the Diurnal Motion does naturally imply fixed Poles, and a fixed Equator; which infer a different Meridian Altitude of thoſe Poles, and of that Equator, and by conſequence of all the heavenly Bodies, in different Latitudes; which different Altitude may in clear Weather be eaſily obſerv'd by proper

Inſtruments, and thereby that Latitude may be readily diſcovered; ſo does not the ſame Diurnal Motion at all imply any *Phænomena*, whence the Longitude may be diſcover'd to us: Becauſe the ſame Parallel ſtill bears, through its whole Circumference, the ſame Relation to thoſe Poles and that Equator, without any Difference. The Diurnal Motion therefore, which affords an obvious Foundation for the Invention of the Latitude of every Place on the Earth, affords us no ſuch Foundation for the Invention of the Longitude of the ſame Places. Nor is it therefore an eaſy Problem, either aſtronomical or practical to diſcover the ſame.

As to the Methods hitherto tryed, they are either Celeſtial, or Terreſtrial; and may be reduc'd to theſe Seven, Four that are *Celeſtial*, and Three that are *Terreſtrial*.

(1) The Eclipſes of the Moon.

(2) The Eclipſes of the Sun.

(3) The Eclipſes of Jupiters Planets.
(4) The Motion of the Moon.
(5) The Variation of the Needle.
(6) Clocks, or Watches.
(7) The Log Line or Dead Reckoning.

Firſt, The Eclipſes of the Moon are uſeful for the Longitude. For its Immerſions into the Earths Shadow, its neareſt Diſtances to that Center, and its Emerſions therefrom, are all at diſtinct and known Points of abſolute time. So that where and when they can be nicely obſerv'd; and the Difference of the apparent times at every Meridian noted; the reſpective Longitudes of thoſe Places may be thereby found in time; and by allowing 15 Degrees of the Equator to an Hour, may be found in Degrees alſo.

Secondly, in the ſame manner may the Eclipſes of the Sun be made uſe of; eſpecially as now improv'd by our great Aſtronomer Mr. *Flamſteeds*

Conſtruction of them; and as they will, we hope, be farther improv'd by Mr. *Whiſtons* actual *Exhibition* of them, in his Inſtrument, juſt ready for Publication. Which Method, by the Difference of the apparent time of any Part of the Eclipſe in different Places, gives the Difference of Meridians, or of Longitude in the like manner as before.

Thirdly, The Eclipſes of Jupiters Satellits afford another like Method for the Diſcovery of the Longitude; and that on the ſame Foundation with thoſe of the Moon.

Fourthly, the Motion of the Moon, with its Diſtance from the Sun, or rather its Appulſe to and Occultation of thoſe fixed Stars that ly along its Courſe, is another remarkable Method for this purpoſe; and is of the ſame Nature with the Eclipſes of the Sun as to this matter.

Theſe Four may juſtly be called *Celeſtial*, or *Aſtronomical* Methods of diſcovering the Longitude, becauſe they make uſe of the Celeſtial Bodies, or of the Stars in order to that End. The Three *Terreſtrial* Methods are as follows.

5ly, The Variation of the Needle from the North is now, eſpecially ſince Dr. *Halleys* noble Obſervations and Map thereto relating, become one Method for the Diſcovery of the Longitude; particularly in thoſe Parts, where that Variation is beſt known, and the North and South Poſition of its Lines are moſt remarkable. For by croſſing the Meridians there, you alſo croſs the Curves of equal Variation, and diſcover in ſome meaſure your Longitude thereby.

Sixthly, The Uſe of Clocks or Watches at Sea is another Method; and was attempted by the famous *Hugenius*. And indeed if they could be exactly kept to an even motion, and ſo ſhew the Hour at any one certain place at Land; the Compariſon of the Time known by that Clock or Watch, with the apparent time at the Ship known by the Sun or Stars, or another Clock or Watch regulated by them, would diſcover the Longitude from the Place to which that firſt Clock or Watch was adjuſted, in time, and ſo, as before, in Degrees alſo.

Seventhly, The Log-line and Dead Reckning, when all fails, is the laſt Remedy in this caſe; and from thence the Seamen gueſs, as well as they can, by the Angle and length of their Courſe, what Longitude and Latitude they are in: And when by Obſervation they find their Error in Latitude, they conclude upon a proportionable one in Longitude alſo. And ſo for want of a ſure Guide, either Celeſtial or Terreſtial, they are forc'd to depend on this; which yet is, as well as the reſt, very uncertain and inaccurate.

For to come to the Reaſons of the ſmall Succeſs of theſe ſeveral Methods.

As to the two firſt, the Eclipſes of the Sun and Moon; to ſay nothing here of the ſlowneſs of the Moon's Motion, which renders any great degree of exactneſs impoſſible; or of the difficulty of Calculation and Conſtruction, eſpecially in the Sun's Eclipſes; and of Obſervations in both: The ſingle rareneſs of theſe Eclipſes, which is not ſeldom made ſtill rarer by cloudy Weather, renders them of very little uſe in Navigation.

As to the third Method, by the Eclipſes of *Jupiter*'s Planets; this muſt be own'd of much greater uſe: Since the quickneſs of their Motion, eſpecially as to the innermoſt, makes the Moment of their Immerſion into, or Emerſion from *Jupiter*'s Shadow very diſtinct and nice; and their frequency, which is almoſt one for every Day, renders them fit for the conſtant uſes of Navigation. Nor have we hitherto had any other Method ſo uſeful at Land as this. Yet are there great Difficulties belonging to this Method; eſpecially at Sea. The beſt Tables of their Motions are hitherto too imperfect to be at all times depended on, as to the exact abſolute Time of their Celebration: And they require Teleſcopes of ſuch a length as have not hitherto been manageable at Sea, in that ſtate of Toſſing and Agitation, which Ships there are ſubject to: Which difficulties, added to the impoſſibility of ſeeing theſe Eclipſes for about three Months every Year, when *Jupiter* is near the Sun, renders this Method at preſent of ſmall uſe in Navigation.

Nor can the fourth Method, or the diſtance of the Moon from the Sun, with its Appulſe to, or Occultation of thoſe fixed Stars, which lye along its courſe, give us the Longitude to ſufficient exactneſs. For, to ſay nothing here of the ſlowneſs of the Moon's

Motion, the want of the utmoſt accuracy of even the place of ſome of theſe fixed Stars themſelves, and of the Sun it ſelf; or of the neceſſity of the uſe of ſmaller Teleſcopes, even in this Caſe, as well as of the trouble of the Calculation and Conſtruction, which are leſſer Difficulties here alſo; 'Tis plain the Theory of the Moon, eſpecially in ſome poſitions, is not exact enough hitherto for our purpoſe; as not ſerving for this Longitude nearer than to two or three Degrees: whereas the Seamen want it within one Degree, or leſs. Tho' indeed it muſt be allow'd, that if the Moon's Theory could be once ſo far perfected, that its place might be with certainty calculated nearer than to two Minutes of a Degree, this would be a very uſeful Method in order to the Diſcovery of the Longitude at Sea. Which Improvement therefore of it's Theory is a thing highly deſireable in Aſtronomy.

We come now to the *Terreſtrial* Methods, and to thoſe difficulties which render them alſo incapable of diſcovering the Longitude, with that certainty, and to that degree of exactneſs, which the purpoſes of Navigation require. Thus the Curve lines of the Variation of the Needle, which is the firſt Terreſtrial Method, are of ſmall uſe, becauſe the Laws of that Variation are not yet brought to a ſufficient certainty, notwithſtanding the moſt uſeful endeavours of Dr. *Halley* in that Matter: The Neighbourhood of Iron Mines, of Iron, or of Loadſtones themſelves, does ſometimes diſturb the general Rules, and deceive the Obſervers of that Variation: The Poſition of thoſe Curves, too far Eaſtward and Weſtward, in a great part of the World, renders this Variation uſeleſs as to any general Diſcovery of the Longitude: and even there where the Poſition of theſe Curves is the moſt advantageous, as it is about the Cape of Good Hope, and a conſiderable way on both ſides of it, yet is the diſtance of thoſe Curves for the difference of one Degree of Variation, about 100 Geographical Miles, *i. e.* near two Degrees of a great Circle; and ſo this Method is incapable of ſhewing the Longitude very nicely in any Caſe whatſoever.

Thus the ſecond Terreſtrial Method, by Clocks or Watches, tho' the eaſieſt to underſtand and practice of all others, has been ſo long in vain attempted at Sea, that we ſee little Hopes of its great uſefulneſs there. Watches are ſo influenc'd by heat and cold, moiſture and drought; and their ſmall Springs, Wheels, and Pevets are ſo incapable of that degree of exactneſs, which is here requir'd, that we believe all wiſe Men give up their Hopes from them in this Matter. Clocks, govern'd by long Pendulum's, go much truer: But then the difference of Gravity in different Latitudes, the lengthening of the Pendulum-rod by heat, and ſhortening it by cold; together with the different moiſture of the Air, and the toſſings of the Ship, all put together, are circumſtances ſo unpromiſing, that we believe Wiſe Men are almoſt out of hope of Succeſs from this Method alſo.

And as for the Log-Line, and Dead-Reckoning, which is the third Terreſtrial Method, they were the known deficiencies of this common way, as alter'd by Storms, and Currents, and the Inaccuracies of the way it ſelf, and of even the Latitude, as commonly taken; together with the too frequent and enduring cloudy Weather, when they can take no Latitude at all; which have occaſion'd the Seamen to deſire ſome other Aſſiſtance for the Diſcovery before us.

We now come to our laſt Buſineſs, *viz.* to give the World a ſhort Hiſtory of our own Propoſal; from what occaſions, and by what ſteps this our Method was firſt diſcover'd, and has arriv'd at its preſent degree of Maturity. As to which matter, the Reader is to know, that ſomewhat above a Year ago, Mr. *Whiſton* and Mr. *Ditton*, with ſome other common Friends, ſpent part of an Afternoon and the Evening together. Mr. *Ditton* took an occaſion, among other common diſcourſe, to obſerve to Mr. *Whiſton*, that ‘ The nature of Sounds would ‘ afford a method, true at leaſt in ‘ Theory, for the diſcovery of the ‘ Longitude’; ſince *The difference between the apparent time, where the Sound is made, and where it is heard; abating only the time for its diffuſion, which was now well known; is the difference of the Longitude of thoſe two Places in time.* Mr. *Whiſton* immediately own'd the truth of the Propoſition, and added, ‘ That ‘ as to the Propagation of Sounds, he ‘ remembred to have himſelf plainly 'heard the Exploſion of great Guns 'about 90 or 100 Miles, *viz.* when 'the *French* Fleet was engag'd with 'Ours, off *Beachy-head* in *Suſſex*; '[which was *A. D.* 1690.] and 'himſelf was at *Cambridge*; and that 'he had been inform'd, that in one 'of the *Dutch* Wars, the ſound of the 'like Exploſions had been heard in'to the very middle of *England*, at 'a much greater diſtance. Upon 'this, Mr. *Whiſton*, when they part'ed, told Mr. *Ditton*, that he took 'the thing to be ſo conſiderable, that 'tho it had been diſcourſed of in 'mix'd Company, after an unguard'ed manner, yet he look'd on it as 'fit to be conceal'd; ſince no body 'could tell, what Improvements might 'on farther Conſideration be built 'upon ſuch a Foundation.' Which Advice Mr. *Ditton* follow'd; and accordingly deſir'd and obtain'd the Silence of thoſe, that had then heard, what had paſs'd. This Propoſition about Sounds, and their diſtant Propagation, with reſpect to the Longitude, did upon this ſo fix it ſelf in Mr. *Whiſton*'s Mind, and did occaſion ſuch Improvements there, that in leſs than two Days time he brought a ſmall Paper to Mr. *Ditton*, containing a Scheme, how that Theory of Mr. *Ditton*'s about Sounds might be reduc'd to Practice, and be actually apply'd to the diſcovery of the Longitude at Sea; which was then not much unlike the former branch of the following Eſſay, only more imperfect: Which Scheme Mr. *Ditton* approv'd of. Soon after this Mr. *Ditton* imparted this Diſcovery to a very good Friend, belonging to the Admiralty, in order to gain farther light as to its practicableneſs at Sea; and that proper Queſtions might by him be ask'd of Seafaring Men relating thereto, without any Suſpicion; which could not well be avoided if we our ſelves had ask'd them; eſpecially ſince the Notion was then got abroad, that we had a Project about the Longitude to propoſe to the World. The reſult of this Enquiry was, that thoſe Sea-men our Friend enquir'd of, did not remember to have heard Sounds at Sea any whit near ſo far as the beforemention'd Examples ſhew'd they had been heard at Land; which difficulty put ſome ſtop to our Progreſs for a little while. However, at laſt, after farther enquiry, the final reſult was this, That tho' Sounds were not ordinarily either at Sea or Land heard very far, yet that was not at Sea, more than at Land, any certain Argument, that they could not ſpread ſo far; becauſe Sounds had been heard a full Degree at leaſt, or 60 Geographical Miles over Sea, even without any extraordinary Contrivance, either at the ſounding Body, or the Ear; both which were yet, for certain, capable of great improvements, in order to the enlargement of that diſtance. So that the Objection ſtarted againſt the ſpreading of Sounds at Sea ſeem'd to be in a manner over, and we at liberty to proſecute our Deſign, as before, of diſcovering the Longitude by means of it. About this time Mr. *Whiſton* diſcover'd and propos'd a great Improvement of his own to this Method; *viz.* That the Guns, which were to make the Exploſions in the former Caſe, might alſo carry Shells, full of Powder, or ſuch other combuſtible Matter, as would take fire at the utmoſt Altitude; and thereby certainly and exactly exhibit the point of the Azimuth, and the Diſtance of the ſounding Body; and ſo join the uſe of the Eye and Ear together for the ſame purpoſe. Tho' at the firſt he muſt own he ſuſpected, that the Apparent Diameter of that Light or Fire would in great diſtances be ſo ſmall, as not to be there viſible. In this very juncture a day of extraordinary Fire-works happen'd [it was the Thankſgiving day for the Peace, *July* 7th, 1713.] the Contemplation of which, did much revive and encourage this Notion: and the certain Account he ſoon had, that thoſe Fire-works, nay, the ſmall Stars, into which the Rockets commonly reſolv'd themſelves, were plainly viſible no leſs than 20 Miles, put an end to his doubts immediately; and made him very ſecure, that ſuch large Shells as might be fir'd at a vaſtly greater height, would for certain be viſible for about 100 Miles; which he look'd on as nearly the limit of Sounds alſo, as to any purpoſes of Longitude. This Improvement of Mr. *Whiſton*'s, which was alſo then for the main the ſame with the ſecond Branch now contain'd in this Paper, was alſo approv'd of by Mr. *Ditton*, and agreed to as fit to be a part of the former Deſign for the Diſcovery of the Longitude at Sea. Mr. *Ditton* did farther add, for Improvement, a ſure Method of Trigonometrical Calculation, to aſcertain from the Obſervations the horary Difference of Meridians (and by conſequence the Difference of Longitude in Degrees) between the Ship's Place, and that of Exploſion; without computing the Time of the Sound's propagation: but ſince this Method is ſomewhat more operoſe than that, which is propos'd hereafter, he chooſes to omit it. He did alſo firſt obſerve that great Uſe of our Method at Land, in the Surveying of Countries, for the Perfection of Geography; which was alſo readily taken notice of by Sir *Iſaac Newton*, and afterward by Dr. *Halley*, and that both of their own accord, upon our firſt communication of our Method to them. For when Matters were brought to ſo hopeful a Poſture, and neceſſary Tables were preparing for the actual Practice of the whole Method, we began to think of intimating to the Publick, that we had a new Diſcovery, as to the Longitude, to propoſe to the World. Which we ſoon did, by our Letter inſerted in the Paper call'd the *Guardian*, of *July* 14. and repeated by another in the ſame Author's Paper call'd the *Engliſhman*, of *December* 10. following. Having before communicated the matter to the illuſtrious Sir *Iſaac Newton*, as we did afterward to thoſe great Men, Dr. *Clarke* Rector of St. *James's*, Dr. *Halley* of *Oxford*, and Mr. *Cotes* of *Cambridge*. How far we profited by this Communication, and what their Opinions were concerning our Method, we need not ſay: becauſe we do not give Account here of every occaſional Improvement, either of our own or others; and becauſe we now publiſh the intire Method, as it ſtands at preſent, to the whole World, for every one's open Judgment, and the farther Improvements of the skilful. Only ſo far their Opinions and Declarations appear to have been on our ſide, that upon hearing what they and we had to ſay, the Committee of the Houſe of Commons, which was appointed to inquire into this matter, came unanimouſly to a Reſolution in our Favour; and the Legiſlature have thereupon thought fit to paſs an Act, appointing a noble Reward for ſuch as ſhall diſcover a better Method than has been hitherto us'd for the finding the Longitude. Which Reward, whether we have any juſt Claim to, in whole or in part, we do hereby intirely ſubmit to the Sagacity and

Juſtice of thoſe eminent Perſons, whom the Legiſlature has been pleas'd to intruſt with the Tryal, Experiment, Judgment, and Determination of all ſuch Propoſals.

We conclude all with our hearty Wiſhes as *Men*, that this our Deſign may tend to the common Benefit of Mankind: as *Britains*, that it may tend particularly to the Honour and Advantage of this our Native Country; and as *Chriſtians*, that it may tend to the Propagation of our Holy Religion, in its original Purity, throughout the World.

London, July 7.
1714.

William Whiſton, *Humphry Ditton*.

PROBLEM.

To find the LONGITUDE both at Sea and Land.

LEMMATA, *or Preparatory Propoſitions.*

I. ALL Sounds are propagated almoſt evenly; and are obſerv'd to move 14 Meaſur'd, or 12 Geographical Miles in one Minute of Time: *i. e.* one Geographical Mile or Minute of a Degree in five Seconds.

This is well known from the laſt and moſt accurate Obſervations * about the Velocity of Sounds, which are thoſe of Mr. *Derebam.* Only a ſmall Addition of Velocity is to be made, when a ſtrong Wind carries the Sound with it, and Subſtraction when it oppoſes it.

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* *Philoſ. Tranſact.* N°. 247. Sir Iſaac Newton's *Princip. Edit.* 2. p. 343, 344.

II. The Sound of a great Gun may be heard by the Ear, duly aſſiſted, if the Wind be favourable, or ſtill, both by Sea and Land, at the leaſt 100 meaſur'd, or 85 geographical Miles. In the open Sea alſo, the Point of the Compaſs may be nearly determin'd whence it comes.

This is very probable, as to the Diſtance, from many known Experiments *; wherein the Ear, even unaſſiſted, has heard ſuch Sounds much farther. And if the Sound were increas'd by a ſounding Board, which might prevent its diffuſion upwards, and ſo ſpread it farther Horizontally on all ſides; and if the Ear were aſſiſted by a hollow Tube of Metal, of the ſhape of a Bell or Tunnel, apply'd thereto, this Propoſition would ſoon be more indiſputable. Nor is there any great Difficulty, as to the Point of the Compaſs, whence the Sound comes at Sea, where nothing can reflect or echo the ſame in any other than the true Angle.

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* *Philoſ. Tranſact.* p. 156, 201, 247.

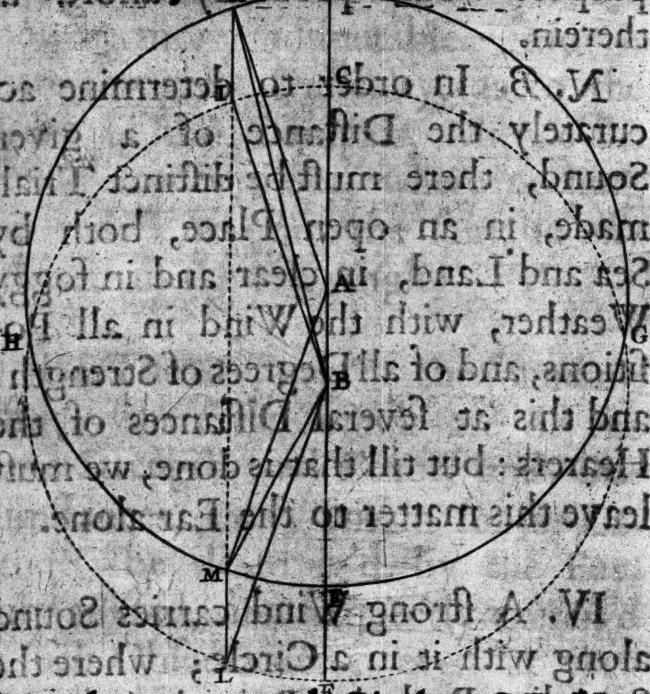
III. The Diſtance of the ſounding Body, where the Sounds are of the ſame Strength, and Tenor, and Circumſtances, may, within ſome Latitude, be determin'd by the Ear, duly aſſiſted, and frequently exercis'd in ſuch Obſervations; even at very conſiderable Diſtances from the ſounding Body.

This appears from the obvious difference of the ſame Sounds at very different Diſtances at preſent; which is in a duplicate Proportion of thoſe Diſtances: and from the great Improvements, Experiments made on purpoſe would probably afford us therein.

N. B. In order to determine accurately the Diſtance of a given Sound, there muſt be diſtinct Trials made, in an open Place, both by Sea and Land, in clear and in foggy Weather, with the Wind in all Poſitions, and of all Degrees of Strength; and this at ſeveral Diſtances of the Hearers: but till that is done, we muſt leave this matter to the Ear alone.

IV. A ſtrong Wind carries Sound along with it in a Circle; where the Sounding Body is a Point in its Axis: and is more or leſs remote from its Center, according as the Wind is greater or leſs.

This appears by the Demonſtration following. Let the Proportion of the Velocity of the Wind, to the Velocity of the Motion of the Air that cauſes the Sound, be as AB to AD.



Let the two equal Circles GDHE, GCHF, be deſcribed upon the Centers A and B; and let any Line, as KL, be drawn Parallel to DF. KI will therefore be always equal to

ML. or to the Velocity of the Wind, and according to its direction; as AM = AK = BL = BI will be equal to the Velocity of the Motion of the Air that cauſes the ſound, and according to its direction; or from the Center to the Circumference of that Circle which includes the ſound. Whence the Diagonals BK, BM will be the diſtance or meaſure of the Equal ſounds; and the points K. M will be in the Circumference of that Circle GDHE of which the ſounding body B is a point in its Axis. Q. E. D.

Corollary (1.) Becauſe the Lines AB and AK, and the Angle BAK are given; the diſtance of equal ſounds BK is alſo given by plain Trigonometry. As the ſame line may be found Geometrically alſo, by applying its length to a ſcale of equal parts.

Coroll. (2.) Two equal Circles, ſliding one upon the other, according the direction of the Axis FD is the readieſt way of ſolving this Problem, for the uſe of Seamen; as being ſo very eaſy in Practice.

V. The Interval of appatent time, in two places, where a Sound is excited, and where it is received; beſides that which is due to the real propagation of the Sound it ſelf; is the Difference of their Meridians, or of their Longitude in Time.

Thus if a Sound, excited juſt at 12 a clock at one place, comes to another after the very ſame Time that is due to the Sounds propagation, as at the diſtance of 14 meaſured Miles, one minute after 12. At the diſtance of 28 ſuch Miles, two minutes after 12. &c. 'tis evident the places are under the ſame Meridian, and have no difference of Longitude. But if it be heard ſooner or later than thoſe times, the Difference is what anſwers to the Temporary difference of their Meridians, or of Longitude, Weſtward or Eaſtward: and ſo is a ſure indication of the ſame. As is very obvious on a little conſideration; and as we ſhall ſhew preſently by example.

VI. An Ordinary Great Gun is eaſily able to caſt a Projectil about a Mile and a quarter, or 6440 Engliſh feet, in perpendicular height.

This appears by that known * Theorem in the Art of Gunnery, which demonſtrates, that the utmoſt Altitude is always equal to half the utmoſt Random of the ſame Gun and Powder:

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* *Halley ap Tranſact. Philoſph.* N° 179. Mr. Anderſon's *Gunn. paſſim.*

which utmoſt Random, of ordinary Great Guns, with a very ſmall charge of Powder, is known to be about two Miles and a half, or 12880 Feet.

N. B. That it appears by the ſame way that the largeſt Great Guns, with their largeſt charge of Powder, are able to caſt a Projectil twice, nay thrice, and even four times the beforementioned height. But becauſe the charges and trouble are in ſuch caſes much greater; and it is uncertain whether the advantages will be proportionably augmented, we chooſe to ſpeak moderately, eſpecially before tryal; and to propoſe nothing here but what is for certain cheap, practicable, and advantagious; and leave thoſe more ſurprizing heights, to the conſideration of the publick afterward; Only with this obſervation, that the Altitude will ever be as the Squares of the Velocity, with which the Projectil is thrown.

VII. The time of the Aſcent or Deſcent of ſuch a Projectil; without the conſideration of the reſiſtance of the Air; (which in the caſe of lead bullets, iron ſhels, or the like denſe bodies is but very ſmall, and in Wood not very great;) is 20″ or $\frac{1}{3}$ of a Minute: and is always the ſame in the ſame height.

This appears from the known Velocity of deſcending or aſcending bodies *, which fall or riſe 16,1 Engliſh Feet in one ſecond of time; and by conſequence 6440 Feet in 20″. thoſe lines of deſcent or aſcent being known to be ever as the Squares of the Times.

VIII. Gunpowder may be diſcharged, or combuſtible matter ſet on Fire at that utmoſt height.

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* Ubi Supra.

This all that deal in Rockets, Bombs, and Mortars do very well know. It being the great buſineſs of their art to proportion the Match or Fuſee to any particular time when it ſhall give Fire; which may as well be always adjuſted to 20″ as to any other number. Nor indeed is it impoſſible to contrive all ſo, that the very beginning of the deſcent ſhall be immediately inſtrumental in that matter, and thereby render the experiment more exact and infallible.

IX. Fire or Light 6440 Feet high, will be viſible, in the night time, when the Air is tolerably clear about 100 meaſured, or 85 Geographical Miles: *i.e.* one whole degree, and 25 minutes of a great Circle, from the place where it is, even upon the ſurface of the Sea.

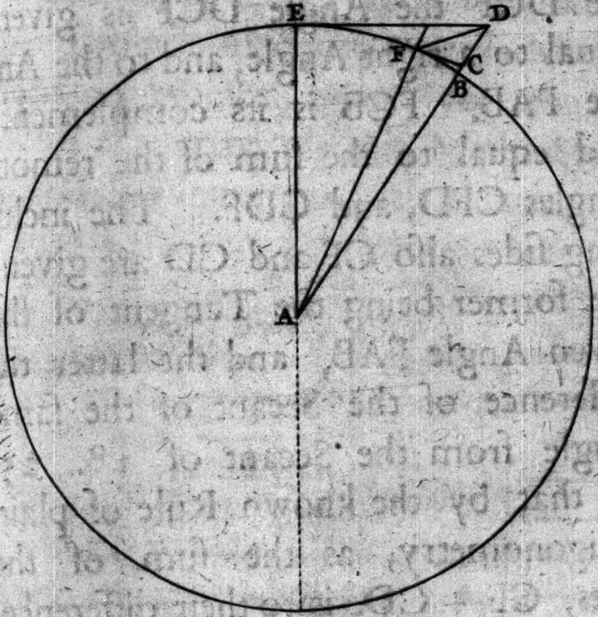
This is eaſily deduced from the Tables of Tangents and Secants, applyed to our Earth ; as will appear preſently. Only it may be noted that the Refraction of Light out of the ſomewhat thinner Air above, into the ſomewhat thicker Air beneath, increaſes this diſtance a little ; as alſo that an Eye upon the Maſt of a Ship will ſee ſuch Fire or Light 10 Miles farther than one on a Level with the Surface of the Sea ; as will appear preſently alſo.

N. B. That the Diſtances this Fire or Light can be ſeen, abating the conſideration of the Atmoſphere, are nearly in a ſubduplicate proportion of the Altitudes; and ſo at four times the height here mentioned, to which yet we have obſerved Projectils may be thrown, this diſtance will be nearly twice as large ; *i. e.* about 200 meaſured, or 170 Geographical Miles ; even without the allowance for refraction, or for the elevation of Mountains, whereon ſuch Guns may be plac'd: both which when allowed for will imply, that 'tis poſſible, if the light be ſtrong enough, to extend this diſtance to between 200 and 300 Geographical Miles, or minutes of a great Circle. A vaſt extent this! and capable of affording proportionably vaſt advantages to Mankind, upon the preſent foundation!

X The Angle ſuch fire or light is ſeen above the Horrizon will very exactly diſcover its diſtance; as will an eaſy obſervation its Azimuth.

The former branch is evident from the nature of a Sphere, with the uſual Tables of Tangents and Secants; and may thus be computed by plain Trigonometry. Suppoſing the eye of the Spectator placed at the ſurface of the Sea; and not conſidering the very ſmall difference by the refraction.

Let A repreſent the Earth's Center, BD the length of the Secant of 1°.



2′5. above the Radius; or 6440 feet. ED the Tangent of the ſame Angle. CB the length of the Secant above the Radius, at any leſſer Angle, as BAF. and CF the Tangent of that laſt Angle. 'Tis evident that the Angle DFC is the elevation of the fire or light above the horizon at any given Point F. and that in the plain Triangle DCF the Angle DCF is given, equal to a right Angle, and to the Angle FAB. FCB is its complement; and equal to the ſum of the remote Angles CFD, and CDF. The including ſides alſo CF and CD are given; the former being the Tangent of the given Angle FAB, and the latter the difference of the Secant of the ſame Angle from the Secant of 1°. 25. So that by the known Rule of plain Trigonometry, as the ſum of the ſides, CF + CD, is to their difference, CF − CD, or CD − CF : So is the Tangent of the Semiſum of the Angles, $\frac{1}{2}$ CFD + $\frac{1}{2}$ CDF = $\frac{1}{2}$ FCB, to the Tangent of their Semidifference. Which Semidifference ſubſtracted at remoter and added at nearer diſtances to that Semiſum ; gives the Angle ſought CFD. Q.E.I.

According to this Rule the following Table is made to every Minute, or Geographical Mile ; for the eaſe of all that may uſe this Method, and may deſire ſome exactneſs therein.

Miles diſtance.	Angle above the Horizon.	Miles diſtance.	Angle above the Horizon.
1	46——25	7	9——0
2	27——42	8	7——55
3	19——16	9	6——50
4	14——40	10	5——55
5	11——50	11	5——20
6	10——20	12	4——54

Miles. diſtance.	Angle above the Horizon.	Miles. diſtance.	Angle above the Horizon.
13	4 —— 30	43	1 —— 1
14	4 —— 8	44	0 —— 59
15	3 —— 52	45	0 —— 57
16	3 —— 37	46	0 —— 55
17	3 —— 23	47	0 —— 53
18	3 —— 11	48	0 —— 51
19	3 —— 0	49	0 —— 49
20	2 —— 50	50	0 —— 47
21	2 —— 41	51	0 —— 45
22	2 —— 33	52	0 —— 43
23	2 —— 25	53	0 —— 41
24	2 —— 18	54	0 —— 39
25	2 —— 12	55	0 —— 38
26	2 —— 6	56	0 —— 36
27	2 —— 1	57	0 —— 34
28	1 —— 55	58	0 —— 32
29	1 —— 50	59	0 —— 31
30	1 —— 46	60	0 —— 30
31	1 —— 41	61	0 —— 28
32	1 —— 37	62	0 —— 26
33	1 —— 33	63	0 —— 25
34	1 —— 28	64	0 —— 24
35	1 —— 24	65	0 —— 23
36	1 —— 20	66	0 —— 21
37	1 —— 17	67	0 —— 20
38	1 —— 14	68	0 —— 19
39	1 —— 12	69	0 —— 18
40	1 —— 10	70	0 —— 17
41	1 —— 7	71	0 —— 15
42	1 —— 4	72	0 —— 14

Miles diſtance.	Angle above the Horizon.	Miles diſtance.	Angle above the Horizon.
73	0 — 13	80	0 — 5
74	0 — 12	81	0 — 4
75	0 — 11	82	0 — 3
76	0 — 9	83	0 — 2
77	0 — 8	84	0 — 1
78	0 — 7	85	0 — 0
79	0 — 6		

N. B. It appears by this Table that the diſtance will never be leſs exact in this Method than is the Obſervation of the Altitude; ſince one Mile here never correſponds to leſs than one Minute; but that generally the diſtance is much more exact than the Obſervation: Since one Mile commonly correſponds to conſiderably more than one minute; nay at very near diſtances to more than one whole degree; as is evident by inſpection. As for the obſervation of the Azimuth, 'tis too eaſie to need any demonſtration.

N. B. If the Eye be elevated above the ſurface of the Sea, it will ſee the fire or light farther; according to the following Table.

Miles diſtant.	Elevation in feet,
1	1
2	4
3	8
4	15
5	23
6	34
7	45
8	57
9	71
10	88
11	107
12	128

XI. If the fire or light can be rendred compleatly viſible during the intire time of the aſcent or deſcent, as in the ordinary Sky-rockets, its Diſtance may be exactly determin'd alſo from the time it appears above the Horizon, by the uſe of the following Tables, even without the knowledge of the Angle of Elevation.

A Table of the number of feet that Bodies fall or riſe, as far as 20″ of time.

″	feet.	″	feet.
1	16.1	11	1948
2	64.4	12	2318
3	145	13	2721
4	259	14	3156
5	402	15	3622
6	580	16	4122
7	789	17	4653
8	1030	11	5216
9	1294	19	5812
10	1610	20	6440

A Table of the Exceſs of the Secants in Feet, above the Earths Semidiameter, as far as 1°. 2′5.

′	feet.	′	feet
1	1	15	199
2	4	16	227
3	8	17	256
4	15	18	288
5	23	19	321
6	34	20	357
7	45	21	393
8	57	22	430
9	71	23	470
10	88	24	512
11	107	25	556
12	128	26	601
13	151	27	647
14	174	28	695

′	feet.	′	feet.
29	745	58	2991
30	798	59	3093
31	853	60	3198
32	909	61	3305
33	968	62	3415
34	1026	63	3526
35	1088	64	3639
36	1151	65	3755
37	1216	66	3870
38	1283	67	3988
39	1352	68	4118
40	1422	69	4229
41	1493	70	4353
42	1569	71	4479
43	1642	72	4608
44	1720	73	4735
45	1800	74	4866
46	1882	75	4998
47	1963	76	5132
48	2047	77	5269
49	2134	78	5407
50	2222	79	5546
51	2312	80	5687
52	2404	81	5830
53	2497	82	5974
54	2592	83	6121
55	2688	84	6271
56	2787	85	6422
57	2887		

N. B. The Rule for Practice is this: Obſerve the Number of the Seconds of Time that you ſee the Fire or Light, either aſcending or deſcending, in the former Table; with its correſponding Number of Feet. Take this Number of Feet out of the entire Number 6440, and keep the Remainder. For where that Remainder is found in the latter Table, you will find the true Diſtance over againſt it. *e. g.* Suppoſe the Light or Fire is obſerv'd to take up 12″. or a fifth Part of a Minute, in its viſible Aſcent or Deſcent. The correſponding Number of Feet in the former Table is 2318, which deducted from 6440, leaves 4122, for the Difference: Which Number in the latter Table correſponds to ſomewhat above 68′. and ſhews that the real Diſtance ſought, is ſomewhat above 68 Minutes, or geographical Miles. The Demonſtration is eaſy from the former

Scheme. For $DB - DC = CB$, and ſo $DA - DC = CA$. or the Difference of the Secant of 1°.25′. and of any Part of it viſible in another Horizon, as at *F*, is equal to the Secant of that Angle *DAF*, or of the Arch *BF*, which is the Diſtance required. Only if the Bottom of the Atmoſphere be too thick to permit the Light or Fire to be ſeen to any certain Altitude, allowance muſt be made for the ſame, in the uſe of theſe Tables.

XII. When a Sound and a Light are made at the ſame Place, either at the ſame time, or at any given Interval; the Diſtance of ſuch Sound and Light from the Auditor or Spectator may be exactly determin'd.

For if they are made at the very ſame time, the Difference of the Velocity of Light, which is, phyſically ſpeaking, inſtantaneous, and of Sound, which goes 12 geographical Miles in a Minute, will, with great Exactneſs, determine that Diſtance. And if there be a given Interval between them, it is eaſily allow'd for.

XIII. If the Longitude or Latitude of one Place be known, and the Diſtance and Poſition of another be alſo known; the Longitude and Latitude of this other Place is known alſo.

This is too obvious to need a Demonſtration; and may be eaſily ſhew'd on a Map, with a Pair of Compaſſes, apply'd to the Scale of that Map.

XIV. If the Longitude or Latitude of one Place be known, and its Diſtance from another be known alſo, and the Longitude of that other Place be otherwiſe known, its Latitude is thereby known. And if its Latitude be otherwiſe known, its Longitude is thereby known alſo.

This is alſo too obvious to need a Demonſtration; and may be ſhewed on a Map, as well as the foregoing.

XV. Hulls of Ships, without Sails or Rigging, may be fixed at Sea in all ordinary Caſes, by Anchors; and in extraordinary Caſes, where the Ocean is vaſtly deep, by Weights let down from the Hulls quite through the upper Currents into the ſtill Waters below, as near as poſſible to the Bottom.

This Matter belongs to Tryal and Experimenrs, and is not to be here particularly demonſtrated. Only we may obſerve, that the lower Parts of the Waters in the Ocean are commonly found to be free from the Currents and Motions of the higher Parts; and that the Method by which thoſe very Currents are diſcovered, is no other than by thus letting down the Lead far below them; which, tho' it touch not the Bottom, yet makes the Boat out of which the Lead is thrown, in the Words of an Eye-Witneſs, [*] *ride as firmly as if it were faſtened by the ſtrongeſt Cable and Anchor to the Bottom.*

N.B. If any Current or ſtrong Wind does, in ſome meaſure, carry away ſuch an Hull, with any ordinary Lead, or Weights, care is to be taken that the Cord or Chain be upward as ſmall, and make as little Reſiſtance to the flowing Water as poſſible; and that the ſame Cord or Chain with its Weights or Leads below, be as large and cumberſome, and make as great Reſiſtance to the ſtill Water below, as poſſible: that ſo the Motion of the Hull may be inſenſible. Note alſo that in caſe there appear ſtill ſome Motion in the Hull, the Mariners are nicely to obſerve its Velocity and Direction; and at convenivenient Seaſons to bring it back again, as near as poſſible, to its original Station.

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[*] Philoſ. Tranſ. *No.* 36. *Abridg. Vol.* 3. *p.* 555, 556.

N. B. Theſe Hulls may be fixed in proper Places as to Latitude, by the known Methods of obſerving the Latitude; and as to Longitude, by Eclipſes of the Sun, or Moon, or of *Jupiter*'s Planets, or by the Moon's Appulſe to fixed Stars; or rather by an actual Menſuration of Diſtances on the Surface of the Sea by Trigonometry, juſt as Monſieur *Picard* and *Caſſini* meaſur'd the Length of a Degree of a great Circle on the Land; while the Light to be thrown up from the Ships will afford the ſame Advantage that any elevated Mark does at Land, and while the vaſtly greater Length of a Baſis or meaſur'd Line on the Shore, the vaſtly greater Diſtances of the Ships; and the much greater Evenneſs of the Surface of the Sea than of the Land, do give us hopes of more Exactneſs in this Way of Menſuration than in any other.

N. B. By the ſame Method, if done with ſufficient Accuracy, we may alſo hope to diſcover the Quantity of a Degree in all ſorts of great Circles, and perhaps more exactly than even Monſieur *Picard* or *Caſſini* have been able to do: becauſe we may hereby actually meaſure a much larger Portion of ſuch great Circles than they could. Which Advantage of this Method is in itſelf very conſiderable alſo.

XVI. If the Altitude of the Sun, at the beſt Advantage, can be taken within four Minutes of a Degree at Sea or Land; the time is thereby determined to about half a Minute: if to two Minutes of a Degree, the time is determin'd to about a quarter of a Minute, even in our Latitude; while nearer the Equator the like Limits determin the time ſtill more exactly.

This the Aſtronomers well know: and any that obſerve in common Quadrants how an Hour, in the middle between Noon and either Morning or Evening, contains uſually about 7 or 8 Degrees of Altitude; while no leſs than 15 Degrees makes an Hour upon the Equator, will eaſily agree to this Propoſition.

XVII. The beſt time for the exact Diſcovery of the Hour at Sea, and of adjuſting all Watches or Movements to ſhew the ſame afterwards, is that of the riſing and ſetting of the Sun; that is, in caſe Allowance be made for the Horizontal Refraction of his Rays; but not otherwiſe.

For if the time while the whole Body of the Sun is riſing or ſetting, which may be very nicely obſerv'd at Sea, be added at Night to, and ſubſtracted in the Morning from, the Time that any Table of its riſing and ſetting, or a particular Trigonometrical Calculation, does determine; the Sum in the firſt, and Difference in the ſecond Caſe will give the true Time when the Sun's Center will appear to be in the very Horizon. And this becauſe the Sun's Horizontal Refraction is obſerv'd to be very nearly equal to his apparent Diameter.

N. B. The Exact time of the Sun's riſing and ſetting, at all Declinations, and in all Latitudes, is found by the following Rule of Trigonometry.

Out of half the Sum of the Complement of the Sun's Declination, and of the Complement of the Latitude of the Place, and of an Arch of 90°. deduct ſeverally the two former Sides, to gain two Differences. Then ſay,

As the Rectangle of the Sines of thoſe two former Sides : to the ſquare of the Radius : : ſo is the Rectangle of the Sines of thoſe two Differences : to the Square of the Sine of half the Angle at the Pole, included between the ſame two Sides, which Angle is the Meaſure of the Time.

For Example. Suppoſe an Hull of a Ship was fix'd in the Latitude of *London*, and there were occaſion to compute exactly the Time of the riſing and ſetting of the Sun, for the longeſt Day of the Year. The Calculation is thus.

Compl. of Declin.	66° — 31′	
Compl. Lat.	38 — 30	
Quadrant.	90 — 00	
Sum	195 — 01.	
Half	97° — 30′ — 30″	
Deduct.	66 — 31 — 00	
First Differ.	30 — 59 — 30	
Deduct from the former Half	38 — 30 — 00	
Second Differ.	59 — 00 — 30	
Log ſin. 66°. 31′. 00″.	9. 9624527.	*A*
Log. ſin. 38. 30. 00	9. 7941496.	*B*
A + *B*	19. 7566023.	*C*
Log. rad. ſquare	20. 0000000.	*D*
Log. ſin. First diff.	9. 7117341.	*E*

Log. ſin. Second diff. 9. 9331794. F
$E + F$ 19. 6449135. G
$D + G$ 39. 6449135.
$D + G - C$ 19. 8883112.
$\frac{1}{2}$ = 9. 9441556. or
(61°. 33′. 44″.
Its double 123°. 7′. 28″. or
(8^h. 12′. 30″.

Note alſo that the Amplitude cannot be exactly taken even at Sea, without the like Allowance for Refraction. And the Difference of Amplitude, when the firſt Edge of the Sun touches, and the laſt leaves the Horizon, is to be added or ſubſtracted in this Caſe, to that when it appears to be half ſet; in order to obtain the Sun's true Amplitude: as well as we added or ſubſtracted the Difference of time before, for the exact Adjuſtment of the true Moment of its riſing and ſetting.

The Solution of the Problem.

Let a great Gun, with a Shell that will take Fire at its utmoſt Altitude, be diſcharg'd perpendicularly 6440 Feet high above the Surface of the Sea, every Night exactly at 12 a-Clock, at all convenient Diſtances and Situations, and from known Places. This Diſcharge will, by the Diſtance and Point of the Compaſs of its Sound, nearly give the Longitude and Latitude to all Places or Ships within the hearing thereof: And it will, by the ſame Diſtance and Azimuth of its Light or Fire, exactly give the ſame Longitude and Latitude to all Places or Ships within the Sight thereof; according to the foregoing Lemmata. *Q. E I.*

For Example: Let us ſuppoſe an Hull fixed in a known place, 30 Degrees more Weſtward than the Meridian of *London*; and that every Midnight its Great Gun is diſcharged, as before; and that a Ship ſailing by at

54",

54′ 40″ after Eleven, ſees the Fire or Light 30′ above the Horizon; *i. e.* by a foregoing Table, at 60 Minutes, or Geographical Miles diſtance. It was therefore 12 a Clock at the Hull, when it was only 11 h. 55′ at the Ship. So that the difference of time is 5′ and the difference of Longitude upon the Equator 1° 15′ and the Ships Longitude from the Meridian of *London* is hereby known to be 31° 15′ Weſtward.

Suppoſe alſo that the Weather be ſuch that only the ſound can be heard, and that it proves to be ſo weak as to be juſtly eſteem'd 60 Geographical Miles, or one Degree of a great Circle, diſtant. This Diſtance anſwers to 5′ of time, for the interval of the Propagation of the Sound: which therefore, if it be heard juſt at 12 a Clock at the Ship, will imply that when the Exploſion was made it was at the Ship only 55′ paſt eleven, the ſame moment that it was full 12 at the Hull; and that therefore the difference of Meridians is the ſame as before, viz. 5″ in time, or 1° 15′ upon the Equator, Weſtward.

Suppoſe farther, that the Light be ſeen at the ſame time that the Sound is heard; with no other than the ſmall difference of the ſlowneſs of the Sound, in compariſon of the inſtantaneous motion of the Light; and that the difference of time between the moſt elevated appearance of the Light and the hearing of the Sound; (which may be eaſily and exactly obſerv'd by any tolerable movement whatſoever, or by a Pendulum, that vibrates half Seconds:) be found to be 4′ 40″ or, which is all one, that the intire difference of the Exploſion made, and of the Sound heard, be 5′ in time. This difference will imply the diſtance of the Ship from the Exploſion to be 60 Geographical Miles. And if the ſound is heard at the Ship 54′ 40″ after Eleven, the difference of Longitude upon the Equator will ſtill be 1° 15′ and the real Longitude from *London* will be 31°. 15′ Weſtward, as before.

If the Azimuth of the Fire or Light be alſo obſerv'd, take with your Compaſſes from your Scale the true diſtance, 60 Minutes, or Miles, and ſet it from the place of the Hull, on the true Angle, in any large Map or Sea-Chart. This will determine the very Point where the Ship is, both for Longitude and Latitude. The ſame thing may be done for the Sound, in caſe the Point of the Compaſs be obſerv'd alſo.

If the Latitude of the Ship be known, take the known diſtance, either by the means of the Light or Fire ſeen, or, if the Weather be too Foggy for that, of the Sound heard; and let it croſs the known parallel of Latitude in the Chart; and this will determine the Longitude. The like is to be done for the Latitude, were the Longitude firſt known. But that not being the uſual caſe, it needs not be farther inſiſted on. Nor need we ſhew how all this may be done by Calculation alſo: ſince thoſe that underſtand any thing of Navigation cannot be to ſeek therein.

N. B. In caſe ſome parts of the Ocean prove ſo very deep and rough that no Hulls can be fixed in them, the way to recover the Longitude, which may be by this means interrupted, is rightly propoſed by Sir *Iſaac Newton* himſelf, in his Paper delivered in to the Committee of the Houſe of Commons, *viz.* to ſail obliquely from the laſt Hull into the Parallel of the next, and ſo along the ſame; till upon approaching to that next Hull the Longitude be anew recover'd, and the Voyage be continued as before. Nor is this Interruption of any conſequence; becauſe it cannot happen but in places where there is no Danger; and where Seamen are under no concern for the knowledge of the Longitude.

OBSERVATIONS.

(1.) IF in all proper Roads of Ships ſuch a great Gun be plac'd and diſcharg'd, exactly every Midnight, whether on Shoars, or Iſlands, or in Hulls, at the Diſtances of about 600 Geographical Miles or 10 Degrees, All Ships that ſail within any tolerable Diſtance may commonly every Week or Ten Days thereby correct their Reckoning, and know their Longitude, as well as Latitude, even when the Heavens are not clear enough to make Celeſtial Obſervations for either.

(2.) The Ordinary Watches, Movements, or Log-Lines in Ships, when thus Corrected and Adjuſted, once in a Week or Ten Days, will well enough ſhew the Longitude during every one of thoſe ſhort Diſtances between the Hulls; and ſo will render the knowledge thereof ſtill more univerſal.

(3.) If one ſuch Row of Hulls be any where found too defective, a double Row may there be laid, Pair by Pair, in the ſame [or equidiſtant] Meridians; with proper Diſtinctions in the Sounds, or the Light, to prevent miſtaking one Row for the other. Nor will there, in this Caſe, be room for almoſt any Uncertainty, ſince even in Cloudy Weather, as much as the Wind carries away the Sound of any one, ſo much will it uſually bring the Sound of another.

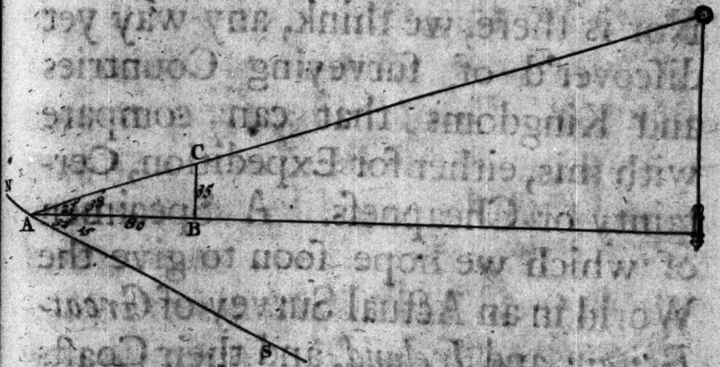
(4.) If it be any where neceſſary, Maſts may be Erected upon Hollow Empty Veſſels, with White Spheres, at their Tops; and theſe Veſſels may be fix'd in proper Places, at equal Diſtances between the Hulls, for the more ſure guiding the Ships in Places of Danger. And ſince from the Top of any Maſt that is 88 Feet High, the Top of another as high may be diſcovered at the Diſtance of 20 Miles, there will hardly be occaſion for more of theſe Veſſels any where than one every 120 Miles; Nor will theſe Maſts and Veſſels be any Annual Charges at all.

(5.) Beſides the great Guns, and their ſolemn Exploſions, In proper Places, at ſeveral Havens, where there is any Danger at the Entrance of Ships, as well as at other convenient Promontories jetting out into the Sea, a Rocket may be thrown up from the Top of a Neighbouring Steeple, or Hill, or the like moſt elevated Place every Midnight, for the Seamens better Direction and Security.

(6.) Signals of all Sorts may be given by this Method, by mutual Agreement. As ſuppoſe in Storms we would know which way, and how ſtrong the Wind is at the neareſt Exploſion, *&c.* Ships may thus give Signals of Diſtreſs to the Hulls, or to one another. The News of great Events may be alſo this way carried very ſoon over the Sea; eſpecially, if any Ships were plac'd within Sight and Hearing of each others Signals, as a Fleet may ſail in Times of Peace, *&c.* In ſhort, no one knows how far this Method of Communication by theſe Kinds of Signals may be improv'd; and how great a Convenience may hence ariſe to the ſeveral Parts of the Globe, eſpecially in the Way of Trade and Commerce; and even for the Propagation of Knowledge both Divine and Human throughout the World.

(7.) If in any clear Night a ſufficient Number of ſuch Exploſions were made at proper Diſtances in any Country, and convey'd in order from one to another; ſo that the Second Gun were fired when the Light of the Firſt was ſeen, or otherwiſe; with the Obſervation of the exact apparent Times when they were made, when the Light was ſeen, what Angle, or how long that Light was above the Horizon, and what Azimuth it had; both the Longitude and Latitude, as well as the Diſtance and Poſition of all theſe Places, might by this means be readily determin'd at Land; eſpecially if the Experiments were repeated ſeveral times, and were compar'd one with another. And by the ſame Obſervations every where, the Longitude and Latitude, Diſtance and Poſition, of all other Neighbouring Places from thoſe, and ſo from another, might be readily determin'd alſo.

N. B. This Method of Survey is no hard Thing in Practice, even to thoſe that know little of the Mathematicks: For any Right Angle, ſet by a Plummet or Level, with Two Pins or Points, for the Eye and for the Object, does by the Proportion of its Sides give the Angle above the Horizon; by the Angle its Horizontal Side makes with the Meridian, it gives the Azimuth; and by the Interval of Time between the Light and Sound, it gives the Diſtance of every Place from that of Exploſion, according to the Figure following.



Where A B repreſents the Horizontal Side of the Norma or Square, and B C the Perpendicular Side; whoſe Proportion once given, as ſuppoſe 80 to 35, the Diſcovery of the Angle of Elevation C A B is moſt eaſy, as here 23° 38′ Where alſo N S. repreſents the Meridian Line lying from *North* to *South*; and the Angle S A B, ſuppoſe of 32 Degrees, 15 Minutes, repreſents the Azimuth, *Eaſtward.* We need not add that a Plummet of 9˪8 Inches

ches long will vibrate half Seconds, for the Interval of Time between the Light ſeen and the Sound heard. Nor is there, we think, any way yet diſcover'd of ſurveying Countries and Kingdoms that can compare with this, either for Expedition, Certainty or Cheapneſs. A Specimen of which we hope ſoon to give the World in an Actual Survey of *Great-Britain* and *Ireland*, and their Coaſts hereby; if the Publick pleaſe to give us Encouragement and Aſſiſtance therein.

(8.) The way of caſting a Shell 6440 Feet high is very eaſy: for the ſame Force or Charge of Gun-powder that will caſt any Shell 12880 Feet for its utmoſt Random, at the Elevation of 45 Degrees, will certainly caſt the ſame Shell perpendicularly upward 6440 Feet, as we have already obſerv'd. And ſince the time of this entire perpendicular Projection, or Aſcent and Deſcent together, is 40″, or ſome very ſmall Matter more; on Account of the Reſiſtance of the Air; We have another ſure Way of Adjuſting the ſame Projection to that Height; *viz.* by obſerving what Quantity of Powder will caſt the Shell high enough to ſtay very little above 40″ in the Air, before it falls to the Ground.

(9.) This Method of firing Powder, or other combuſtible Matter, at, or very near the utmoſt Height of 6440 Feet, may be well enough put in practice, even tho' ſome conſiderable Error ſhould be committed in the adjuſting the Fuſee to give Fire in 20″. Since the Miſtake of even a Fifth Part, or Four entire Seconds, in that Caſe, would produce but an Error of the 25th Part of the whole Altitude; and the Miſtake of a Tenth Part, or Two Seconds, would occaſion an Alteration of no more than the Hundredth Part thereof.

This is evident, becauſe this Time belongs to the higheſt Part of the Projectils Motion, which is the ſloweſt: And becauſe the Lines deſcrib'd by all Aſcending and Deſcending Bodies are ſtill in a Duplicate Proportion of the Times of ſuch their Aſcent and Deſcent.

(10.) If one or more Rows of ſuch Hulls were laid in the ſame or Equidiſtant Meridians, Southward or otherways, Ships might with greater Safety than formerly go to diſcover thoſe Parts of the Globe which are hitherto undiſcover'd. Nor can we at preſent gueſs what Advantages may thereby accrue to the Parts of the World already diſcovered.

(11.) Every one of theſe Hulls may be Places of Obſervation as to the Variation of the Needle, to the Currents, to the Soil, the Fowls, the Fiſhes, and other *Phænomena* of the ſeveral Places where they are fixed; and an excellent Means of keeping up a mutual Correſpondence between the ſeveral Parts of the Globe, for all uſeful Purpoſes whatſoever.

(12.) As this Method ought to be put in Practice by the Conſent of all Trading Nations; ſo ought every one of the Hulls employ'd therein to have a legal Protection from them all; And it ought to be a great Crime with every one of them, if any other Ships either injure them, or endeavour to imitate their Exploſions, for the Amuſement and Deception of any.

(13.) Since the Charges of the Powder for each Gun will be very ſmall; ſince the Shells and their Contents come to no great Price neither; ſince the Perſons employ'd in the Hulls may be in part taken out of ſuch Places where they are maintain'd at the Publick Charge already; and ſo will require only ſome Additional Rewards, or Future Privileges for ſuch their Service; And ſince the Land-Exploſions, which will be much the moſt numerous, will be withal much the cheapeſt; It will appear, upon the Whole, that the Annual or Conſtant Expences of this Method will be comparatively very ſmall and inconſiderable: eſpecially if they are, as they ought to be, equally diſtributed among the ſeveral Trading Nations of the World.

The Advantages of this Method.

(1.) THIS Method requires no Depth of Aſtronomy, no Nicety in Inſtruments, and but ſeldom any Celeſtial Obſervations at all, either as to the Latitude, or the Hour at the Ship; and ſo is to even the common Sailors the *moſt Practicable.*

(2.) It does generally determine the very Place of the Ship, both as to *Longitude* and *Latitude* at once, and ſo is the *moſt Compendious.*

(3.) It does generally determine the very Place to a few Miles, at the fartheſt; and ſo is the *moſt Accurate.*

(4.) It affords Help even in Cloudy and Foggy Weather, when no Celeſtial Obſervations can be made, and the *Latitude* it ſelf cannot be otherwiſe found, and ſo is the *moſt General.*

(5.) It will frequently afford a double Obſervation Two ſucceſſive Nights, from the ſame Hull to the ſame Ship, and ſo is the *moſt ſecure*.

(6.) It will commonly afford a double way of Obſervation at the ſame time, by the Eye and by the Ear, which will confirm or correct one another; and ſo is the *moſt certain*.

(7.) The more inaccurate Branch, by the Sound, is not only more univerſal than the other; but is alſo much more exact than any Method formerly diſcover'd: So that in the very worſt Circumſtances this way is certainly the *very beſt*.

(8.) It is the moſt undoubted and exact where there is the greateſt Want and Danger: And if it ſhould at all be deficient, it is there only where there is no Danger, and hardly any occaſion for knowing the Longitude, as has been ſhew'd already. So that on all Accounts it is plainly the *moſt Uſeful* and *Advantageous*.

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APPENDIX.

IT is farther humbly propos'd to the Learned, Whether it may not be proper for all Nations, upon this Occaſion, to agree upon one *firſt Meridian*, or beginning of *Longitude*, for the common Benefit of *Geography*? And whether it may not be proper, in that Caſe, to fix it to the *Pike of Tenariff*, as the moſt noted Place already; and as the Place whence the Higheſt and moſt generally uſeful Exploſion muſt in this Method be made every Midnight continually for the Diſcovery of the *Longitude* it ſelf?